Supplementary Materials

Drivers and barriers to substituting firewood with biomass briquettes in the Kenyan tea industry

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Table S1. Firewood demand
Table S2. Tea factory inventory
Table S3. Location of briquette factories
Table S4. Location of sugar factories
Table S5. List of experts contributing to the study
Table S6. Comparison of physical properties between firewood and briquettes
Table S7. Data sources to establish the map

Table S1. Firewood demand.

	Unit	UNEP (2019)	KTDA (2019a,b)	ETP (2020)	This study
Total consumption of all factories					
Number of factories		113	69	14	70
Density	kg/m^3	550	460	NA	460
Calorific value	MJ/kg	15.1	14	14	14
Firewood consumption	m^3	1,643,329	900,000	228,465	900,000
Dry firewood equivalent	tons	903,831	414,000	NA	414,000
Energy consumption	GJ	13,647,847	5,796,000	NA	5,796,000
Consumption of 1 tea factory					
Average per tea factory	m^3	14,543	13,043	16,319	NA
Firewood consumption	m^3	21,382	11,500	16,319	16,000
Bone-dry firewood equivalent	tons	11,760	NA	NA	7,360
Energy consumption	GJ	177,578	NA	NA	103,040
Remarks		Consumption of 113 tea factories, including non-KTDA factories	Consumption of 69 tea factories. The assumed consumption is less than the calculated average	Consumption varies between 11,306 and 24,732 m^3	This study adopted assumptions by KTDA

Note: This study uses average values from the literature; grey highlights are calculated based on the assumptions.

Table S2. Tea factory inventory.

No	Tea factories	County	Region name	Year	Longitude	Latitude
1	Gachege	Kiambu	Aberdare Ranges	2003	36.806723	-0.909257
2	Kambaa	Kiambu	Aberdare Ranges	1974	36.716374	-1.068443
3	Kagwe	Kiambu	Aberdare Ranges	1984	36.726735	-1.005177
4	Mataara	Kiambu	Aberdare Ranges	1964	36.799098	-0.860963

5	Ndarugu	Kiambu	Aberdare Ranges	NA	36.776256	-0.923716
6	Theta	Kiambu	Aberdare Ranges	1981	36.768636	-0.962009
7	Gacharage	Murang'a	Aberdare Ranges	2002	36.856435	-0.743221
8	Gatunguru	Murang'a	Aberdare Ranges	1981	36.900719	-0.638648
9	Githambo	Murang'a	Aberdare Ranges	1977	36.893961	-0.728533
10	Ikumbi	Murang'a	Aberdare Ranges	1971	36.898254	-0.789278
11	Kanyenyaini	Murang'a	Aberdare Ranges	1974	36.915639	-0.679885
12	Kiru	Murang'a	Aberdare Ranges	1993	36.906289	-0.618354
13	Makomboki	Murang'a	Aberdare Ranges	1981	36.844150	-0.804179
14	Nduti	Murang'a	Aberdare Ranges	2002	36.881787	-0.805990
15	Ngere	Murang'a	Aberdare Ranges	1993	36.808416	-0.836885
16	Njunu	Murang'a	Aberdare Ranges	1979	36.877938	-0.844658
17	Chinga	Nyeri	Aberdare Ranges	1963	36.898091	-0.601439
18	Gathuthi	Nyeri	Aberdare Ranges	1978	36.893191	-0.490663
19	Gitugi	Nyeri	Aberdare Ranges	1984	36.875059	-0.517552
20	Iriaini	Nyeri	Aberdare Ranges	1981	36.909840	-0.543880
21	Ragati	Nyeri	Aberdare Ranges	1957	37.158842	-0.391330
22	Kathangariri	Embu	Mt. Kenya	2002	37.450861	-0.406810
23	Mungania	Embu	Mt. Kenya	1973	37.504764	-0.396647
24	Rukuriri	Embu	Mt. Kenya	1983	37.544387	-0.374626
25	Kangaita	Kirinyaga	Mt. Kenya	1966	37.251103	-0.413571
26	Kimunye	Kirinyaga	Mt. Kenya	1979	37.309241	-0.426647
27	Mununga	Kirinyaga	Mt. Kenya	1993	37.217942	-0.464598
28	Ndima	Kirinyaga	Mt. Kenya	1981	37.173666	-0.452418
29	Thumaita	Kirinyaga	Mt. Kenya	1975	37.369366	-0.430065
30	Githongo	Meru	Mt. Kenya & Nyambene Hills	1976	37.585580	0.001538
31	Imenti	Meru	Mt. Kenya & Nyambene Hills	1971	37.598212	-0.063188
32	Igembe	Meru	Mt. Kenya & Nyambene Hills	2009	37.921780	0.165607
33	Kiegoi	Meru	Mt. Kenya & Nyambene Hills	1982	37.923612	0.220037
34	Kinoro	Meru	Mt. Kenya & Nyambene Hills	1984	37.630845	-0.180168
35	Kionyo	Meru	Mt. Kenya & Nyambene Hills	2003	37.611907	-0.111356
36	Michimikuru	Meru	Mt. Kenya & Nyambene Hills	1963	37.849979	0.193183
37	Weru	Tharaka	Mt. Kenya & Nyambene Hills	2002	37.636647	-0.268119
38	Olenguruone	Nakuru	Kericho Highlands	2013	35.623960	-0.562868
39	Kapkoros	Bomet	Kericho Highlands	1976	35.316183	-0.669623
40	Tirgaga	Bomet	Kericho Highlands	2007	35.360545	-0.704266
41	Motigo	Bomet	Kericho Highlands	2015	35.375695	-0.736565
42	Kapset	Bomet	Kericho Highlands	1981	35.251531	-0.542950
43	Rorok	Bomet	Kericho Highlands	2007	35.304443	-0.572803
44	Boito	Bomet	Kericho Highlands	1961	35.231509	-0.565633
45	Kobel	Bomet	Kericho Highlands	2010	35.375362	-0.616804
46	Mogogosiek	Bomet	Kericho Highlands	1984	35.271172	-0.620543

47	Chelal	Kericho	Kericho Highlands	2011	35.105736	-0.502381
48	Litein	Kericho	Kericho Highlands	1966	35.188611	-0.577314
49	Kapkatet	Kericho	Kericho Highlands	1993	35.193952	-0.643539
50	Tebesonik	Kericho	Kericho Highlands	2019	35.102456	-0.575618
51	Momul	Kericho	Kericho Highlands	2002	35.107250	-0.416600
52	Tegat	Kericho	Kericho Highlands	1971	35.209044	-0.384968
53	Toror	Kericho	Kericho Highlands	2009	35.296979	-0.318399
54	Eberege	Kisii	Kisii Highlands	2007	34.686771	-0.917167
55	Ogembo	Kisii	Kisii Highlands	1984	34.730572	-0.815377
56	Itumbe	Kisii	Kisii Highlands	2006	34.781016	-0.782605
57	Nyamache	Kisii	Kisii Highlands	1978	34.820706	-0.860848
58	Kiamokama	Kisii	Kisii Highlands	1976	34.884214	-0.831973
59	Rianyamwamu	Kisii	Kisii Highlands	2011	34.795345	-0.726496
60	Gianchore	Nyamira	Kisii Highlands	2004	34.877875	-0.583032
61	Kebirigo	Nyamira	Kisii Highlands	1971	34.950740	-0.607855
62	Nyankoba	Nyamira	Kisii Highlands	1966	34.919631	-0.759305
63	Nyansiongo	Nyamira	Kisii Highlands	1974	35.016246	-0.760249
64	Sanganyi	Nyamira	Kisii Highlands	1981	34.975116	-0.561549
65	Tombe	Nyamira	Kisii Highlands	1982	34.875871	-0.655310
66	Chebut	Nandi	Nandi Hills & Western Highlands	1972	35.092133	0.201138
67	Kaptumo	Nandi	Nandi Hills & Western Highlands	2009	35.092133	0.201138
68	Mudete	Kakamega	Nandi Hills & Western Highlands	1959	34.768898	0.112974
69	Kapsara	Trans Nzoia	Nandi Hills & Western Highlands	2004	35.158933	1.085551

Table S3. Location of briquette factories.

No	Briquette factory	County	Longitude	Latitude
1	Factory 1	Bungoma	34.65754021	0.612709327
2	Factory 2	Nairobi	36.87213287	-1.321269256
3	Factory 3	Kisumu	34.82585601	-0.069753175
4	Factory 4	Migori	34.56037828	-0.952072087
5	Factory 5	Murang'a	37.13375289	-0.936736910
6	Factory 6	Kisumu	35.18816180	-0.152396479
7	Factory 7	Kisumu	34.82495483	-0.059784375
8	Factory 8	Kiambu	36.83871771	-1.180909875
9	Factory 9	Nakuru	36.58055103	-0.985525266

Table S4. Location of sugar factories.

No	Briquette factory	Town	County	Longitude	Latitude
1	Nzoia	Bungoma	Bungoma	34.65541680	0.568694098
2	Sukari Industries	Ndhiwa	Homabay	34.38560241	-0.820709428
3	Mumias	Mumias	Kakamega	34.50573389	0.364228986

4	West Kenya	Kakamega	Kakamega	34.83166729	0.379895943
5	Butali	Kakamega	Kakamega	34.84041586	0.504338641
6	South Nyanza (Sony Sugar)	Migori	Kisii	34.52958388	-0.891191081
7	Kibos	Kibos	Kisumu	34.81512861	-0.062663648
8	Muhoroni	Muhoroni	Kisumu	35.18713613	-0.152793355
9	Chemelil	Muhoroni	Kisumu	35.13848069	-0.079384952
10	Kwale International (KISCOL)	Kwale	Kwale	39.39575015	-4.529360618
11	Transmara	Nakuru	Nakuru	34.73972355	-1.019525457

Table S5. List of experts contributing to the study.

Name	Type of organization	Location	Interview date	Themes
Expert 1	Briquette company	Kenya	16-12-2020	Supply, SWOT
Expert 2	Briquette company	Kenya	09-03-2021	Supply, SWOT/PESTEL
Expert 3	Briquette company	Kenya	16-12-2020 26-02-2021	Supply, SWOT SWOT/PESTEL
Expert 4	Briquette company	Kenya	04-02-2021	SWOT/PESTEL
Expert 5	Briquette company	Kenya	09-02-2021	Supply, SWOT/PESTEL
Expert 6	Tea company (KTDA)	Kenya	09-02-2021	Demand, SWOT/PESTEL
Expert 6	NGO	Kenya	09-02-2021	SWOT/PESTEL
Expert 7	NGO	Kenya	01-03-2021	SWOT/PESTEL
Expert 9	Research institute	Netherlands	09-02-2021	Supply, SWOT/PESTEL
Expert 10	Government agency (KEBS)	Kenya	22-03-2021	Standards, SWOT/PESTEL
Expert 11	Consultant	Kenya	11-05-2021	SWOT/PESTEL
Expert 12	Research institute	Kenya	15-12-2020	General situation in Kenya
Expert 13	Research institute	Kenya	11-12-2020	General situation in Kenya
Expert 14	International cooperation	Kenya	15-12-2020	General situation in Kenya

Disclaimer: All views, remarks, and opinions of the experts are treated confidentially and not necessarily a reflection of the organization they represent. Experts 12, 13, and 14 were consulted during the research design phase.

Table S6. Comparison of physical properties between firewood and briquettes.

	KTDA target		**KS ISO**	**Interviews**
	Firewood (*Eucalyptus*)	**Briquettes**	**Briquettes**	**Briquettes**
Bulk density	460 kg/m^3	1,200 kg/m^3	-	1,000 kg/m^3
Moisture content	≤ 20%	≤ 10%	12-15%	6-14%
Calorific value	14 MJ/kg at ≤ 20% MC	14 MJ/kg at ≤ 10% MC	≥ 14.5 MJ/kg	15.9-23 MJ/kg
Ash content	-	-	≤ 3%	2-10%
Others	Wet firewood (MC ≥ 30%, should be seasoned for > 6 months)	Combustible with < 1% clinker	-	-

Source: KTDA; KS ISO 17225-7:2014 through personal communication with KEBS; interviews

Table S7. Data sources to establish the map.

Data	Source	Remarks
GPS coordinates of tea factories	Pin-pointed from Google Maps	69 of 70 KTDA-managed factories were located.
GPS coordinates of briquette factories	Pin-pointed from Google Maps	Only 9 out of 30 factories could be located of which 4 were proxy locations.
GPS coordinates of sugar factories	Pin-pointed from Google Maps	11 operational factories were located.
Shapefile: Counties	Open Africa	47 districts in Kenya, https://africaopendata.org/dataset/kenya-counties-shapefile
Shapefile: Agriculture	World Resources Institute	Area of cropland in Kenya, https://www.wri.org/data/kenya-gis-data
Shapefile: Tree plantations	World Resources Institute	Tree plantations in Kenya (non-forests), https://www.wri.org/data/kenya-gis-data